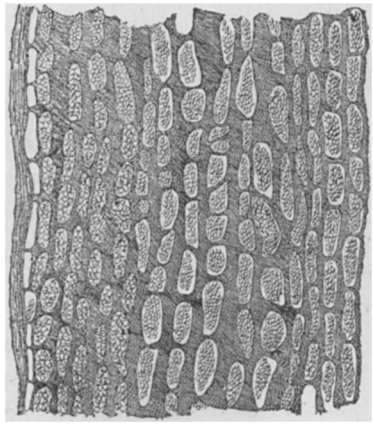
BACTERIA AS A CAUSE OF DISEASE IN PLANTS.

BY PROFESSOR T. J. BURRILL.

CERTAIN diseases of animals are now positively known to be due to the action of the minute organisms commonly known as *bacteria*. They are spoken of as "disease germs" or "spores," and the "germ theory" of disease is very fully discussed in medical literature. Among the best proved examples that the so-called germs are the actual *cause* of disease, we may cite anthrax in cattle, malignant pustule in man, and the diseases of swine and fowl ordinarily known as cholera. Many other contagious diseases of man and the domestic animals are scarcely less clearly known to be due to bacteria, but it has not been shown that they also cause disease and death of plants, except as recently announced by the writer in case of "blight" in pear and apple trees (August, 1880, American Association for the Advance-



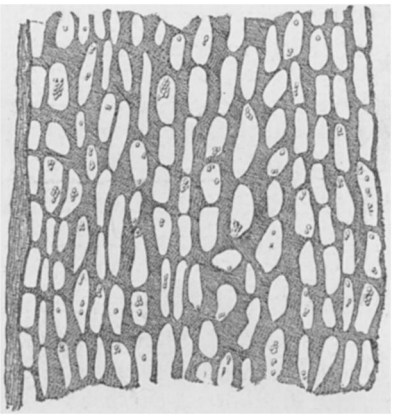
Healthy Pear Bark, showing cells filled with starch. Magnified 125 times.

ment of Science). I am now able to add the "yellows" of the peach with much confidence, without, however, the full investigation given to the former disease.

In 1877 I observed in the fluids of blighting pear trees, great numbers of minute, moving things which were not clearly identified as bacteria until the following year. Their presence was uniformly detected in every examination made (and they were numerous) during the summer of 1878, and the fact was reported to the Illinois State Horticultural Society, in December of that year (Transactions, p. 79). Investigations were not further pros-

ecuted until June, 1880, when the unusual prevalence of the disease called more special attention to it. The same organisms, or those very similar, were as uniformly found in the tissues of apple trees suffering with the disease called twig blight. On diseased parts of both trees, drops of whitish, viscid material were often found, oozing from the bark, and this proved to be almost wholly made up of the bacteria. After some hours' exposure the mass became yellowish, and finally dark-brown. These bacteria are generally double jointed, each article being about .001 mm. (.0000393 in.) in transverse diameter, and about .0015 mm. long. Sometimes, however, the oval single forms are common, and not unfrequently longer ones of several joints are found.

Upon examining the infected tissues, the absence of the starch



Diseased Pear Bark, from limb three weeks afer blight commenced. Magnified 125 times.

granules, so abundant in the healthy cells, was especially marked. Tests revealed the fermentation of this starch with the evolution of carbon dioxide, hydrogen and butyric acid. The other carbonaceous materials in the cells, as sugar, malic acid, &c., doubtless undergoes the same fermentation, but being soluble in water their loss is not rendered evident by the microscope. The cell walls contrary to my expectation, were not found injured, neither was the protoplasm involved in the fermentation.

By passing a thin section of the bark under the microscope, it is possible to find in the same slice, all variations, from perfectly healthy cells to those which have lost the whole of the stored starch, the bacteria likewise varying in numbers as the destruc-

tion of the starch bacteria progresses. How these originally gain entrance to the cells was not made out. There are certainly no pores or other visible openings through which they pass. Water, however, is absorbed by the cell walls, and passes through their molecular spaces in all directions. It may be that in the germ condition the bacteria are really small enough to pass with the water through the walls, notwithstanding the fact the highest powers of our microscopes fail to detect the molecular openings. However this may be, it is positive enough that the adult bacteria do not in this way traverse the cell walls. The evidence is totally against any distribution of the organisms in the tissues by the circulations of water or sap. They slowly make their own way from cell to cell, progressing equally in all directions from the starting point when the same conditions are presented.

On July 1, 1880, I inoculated two pear trees by inserting small pieces of bark from a pear tree in which the disease was in active progress. On the 12th and thereafter, inoculations were made by dipping a clean needle or the sharp point of the blade of a penknife into the viscid substance exuding from diseased bark, diluted or not with distilled water, and thrusting the instrument into the experimental trees. Usually three such punctures were made near each other, but the three were counted as one inoculation.

No visible results followed any of these inoculations during the first eight days, and in some cases for two or even three times this period. In the majority of cases ten to twelve days elapsed before external signs of the disease could be observed. No difference was detected in this or any other respect in the different ways of inoculation. But numerous external applications of the virus were made to the bark and leaves without wounding, none of which seemed to communicate the disease. The trees were examined at least once each day until the 14th of August, 1880, and every observed change carefully noted. Very often the disease could be detected by dissections and microscopical examinations when no external indications were presented, but these were not counted as successful inoculations except in very clear cases.

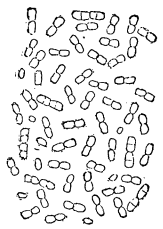
The experiments upon pear trees were made upon trees three years old, Bartlett and Clapp's Favorite, seventy-two in number. The apple trees are Grime's Golden, and the quince, Angers.

The following table gives the results in per cents of the number of successful inoculations:

Number of Experiments.	Kinds of Trees.	Virus from Pear.	Virus from Apple.
36	Pear	54	72
29	Apple	30	Not tried.
4	Quince	100	Not tried.

It will be observed that the virus from the diseased apple limbs was more fatal to the pear than that from blighting pear, showing at least that the disease in the apple is of the same nature as that known as fire blight in the pear. It is quite possible, however, that the greater percentage is due to other causes than the virulence of the inoculating material, and that another set of experiments would show this. The low per centage in case of the apple (30) inoculated with pear virus is partially explained from the fact that ten inoculations were in the bark of portions more than one year old, none of which were successful. As these trees show blight for the most part in the shoots of the current year's growth only, some reason for the failure may be conceived. But four inoculations were made in the quince, all of which communicated the disease. These were made upon the young shoots of a bushy tree which was not otherwise unhealthy.

Since these experiments were made, careful study has convinced me that the death of patches of bark on the trunk and larger limbs of the apple tree is due to the same cause. The disease slowly progresses from the center of infection and kills the tree when the whole circumference becomes involved. Sometimes, however, the liber (the bast cells are not penetrated by the bacteria) forms a complete shield to the inner tissues, and after the outer cellular bark is destroyed a new layer is formed beneath, the old finally falling away.



Blight Bacteria. Magnified 1000 times.

Meteorological conditions probably have some influence, but how much and what is not clear. The disease slowly progresses in winter as well as summer, in dry weather as well as wet. The

sudden appearance often noted is but the blackening of the leaves upon a branch long diseased.

The slow progress of the malady gives the best hope for successful treatment. It has been considered sudden and irregular, with little or no indications of trouble until destruction came; but this is greatly over-stated. Acquaintance with the first appearance in the bark, and careful examination every two or three weeks, will make treatment much more possible than heretofore supposed. The remedy proposed is the old one of cutting away the diseased portions, adding, however, the precaution of taking all infected parts, and not merely such as have become blackish after the ravages are complete, and to observe requisite care in cleansing the knife or other instrument, that by the very process of cure the contamination is not spread. Probably carbolic acid or other antiseptic washes may be useful, but proof from actual and indisputable experiment has not yet been reached.

Very recent examinations of material sent from Michigan conclusively confirms my opinion that the yellows of the peach tree is caused by a similar organism. In the cells of an infected shoot I find very little stored starch, but numerous bacteria. These are seemingly different, under a one-tenth Tolles' or Spencer's objective, from the bacteria of the pear and apple. Compared with the latter, they are long and slender, measuring about .001 mm. by .0035 mm. They consist of several joints, but little longer than wide in what appears to be the typical forms.

The Lombardy poplar trees are also destroyed by these ferment producing agents, following the attacks of certain wood-boring coleopterous larvæ. The latter penetrate the bark and take devious courses through the bark parenchyma and the cambium layer. Starting from their channels, the bacteria slowly spread from cell to cell, until so much of the essential tissue is destroyed that the tree, after some years of hopeless struggle, succumbs. Sometimes the bacteria collect in immense numbers in pockets, which they appear to form in the bark of this tree by absorption of the cell walls. The thick, white mass which they thus form, has the appearance to the unaided eye of pus from sores in the flesh of animals.

The aspen *(Populus tremuloides)* is similarly affected. The young limbs die and the leaves become black in a manner every way similar to those of the pear and the apple.